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Member Stiffness for Frame Analysis of GFRP Reinforced Concrete Structures

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Abstract

The ACI 318 Building Code provides flexural EI stiffness values for elastic analysis of steel reinforced concrete buildings, with a moment of inertia I equal to $0.7I_g$ for columns, $0.35I_g$ for beams, and $0.25I_g$ for flat slabs at factored loads ($1.0I_g$ for columns, $0.5I_g$ for beams, and $0.35I_g$ for flat slabs at service loads). This paper recommends design values of the moment of inertia for analysis of glass fibre reinforced polymer (GFRP) reinforced concrete members based on current ACI 440 design requirements. Results at the factored load level suggest using a value of I equal to $0.4I_g$ for columns and $0.15I_g$ for beams and slabs. At the service load level, recommended values are increased by 50 percent to give $0.6I_g$ for columns and $0.225I_g$ for beams and slabs.

Keywords: analysis; beams; columns; moment of inertia; slabs; stiffness; FRP reinforcement.

1 Introduction

Structural concrete building codes provide values of the flexural stiffness EI of columns, beams, and slabs for elastic (first-order) analysis of steel reinforced concrete building frames [1,2].

For analysis at the factored load level, ACI 318 [1] permits using a moment of inertia equal to $0.7I_g$ for columns, $0.35I_g$ for beams, and $0.25I_g$ for flat slabs. The elastic modulus $E_c = 0.043w_c^{1.5}\sqrt{f_c'} \approx 4700\sqrt{f_c'}\ (MPa)$. Moment of inertia values are approximate and include a stiffness reduction factor ϕ of 0.875 [3,4]. For service loads, the moment of inertia value is taken as 1.4 times the value at the factored load level ($1.0I_g$ for columns, $0.5I_g$ for beams, and $0.35I_g$ for flat slabs) [1]. ACI 318 also provides more detailed values of I that depend on the axial load P, eccentricity e = M/P, reinforcing ratio ρ, and compressive strength f_c' [5,6] (see Table 1).

This paper provides initial design values of the moment of inertia for frame analysis of glass fibre reinforced polymer (GFRP) reinforced concrete members which have a lower stiffness than steel reinforced concrete because of the low stiffness of the GFRP reinforcing bars. Moment of inertia values are provided for columns, beams, and slabs based on ACI 440.1R-15 design guidelines [7].

The flexural EI stiffness for beams and slabs is based on the member thickness required to satisfy long term deflection requirements for gravity load moments only (non-sway frames) using the current ACI 440 design recommendations [7]. Lateral load moments are not included in this part of the analysis. The flexural EI stiffness of columns is based on the nonlinear moment curvature response of column sections using loads defined from the axial load-moment interaction diagram for eccentricity ratios (e/h) between 0.1 to 0.8 and reinforcing ratios from 1 to 3%.

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